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ABSTRACT

This guide is designed for both independent study and class use. It provides the basis for a unit in a science class for the secondary school level. At the undergraduate college level, it provides an outline of activities for a contract as part of an education or science course. The lessons in the guide concentrate on the application of science skills and concepts in identifying and solving water and land environmental problems. (Author/RE)

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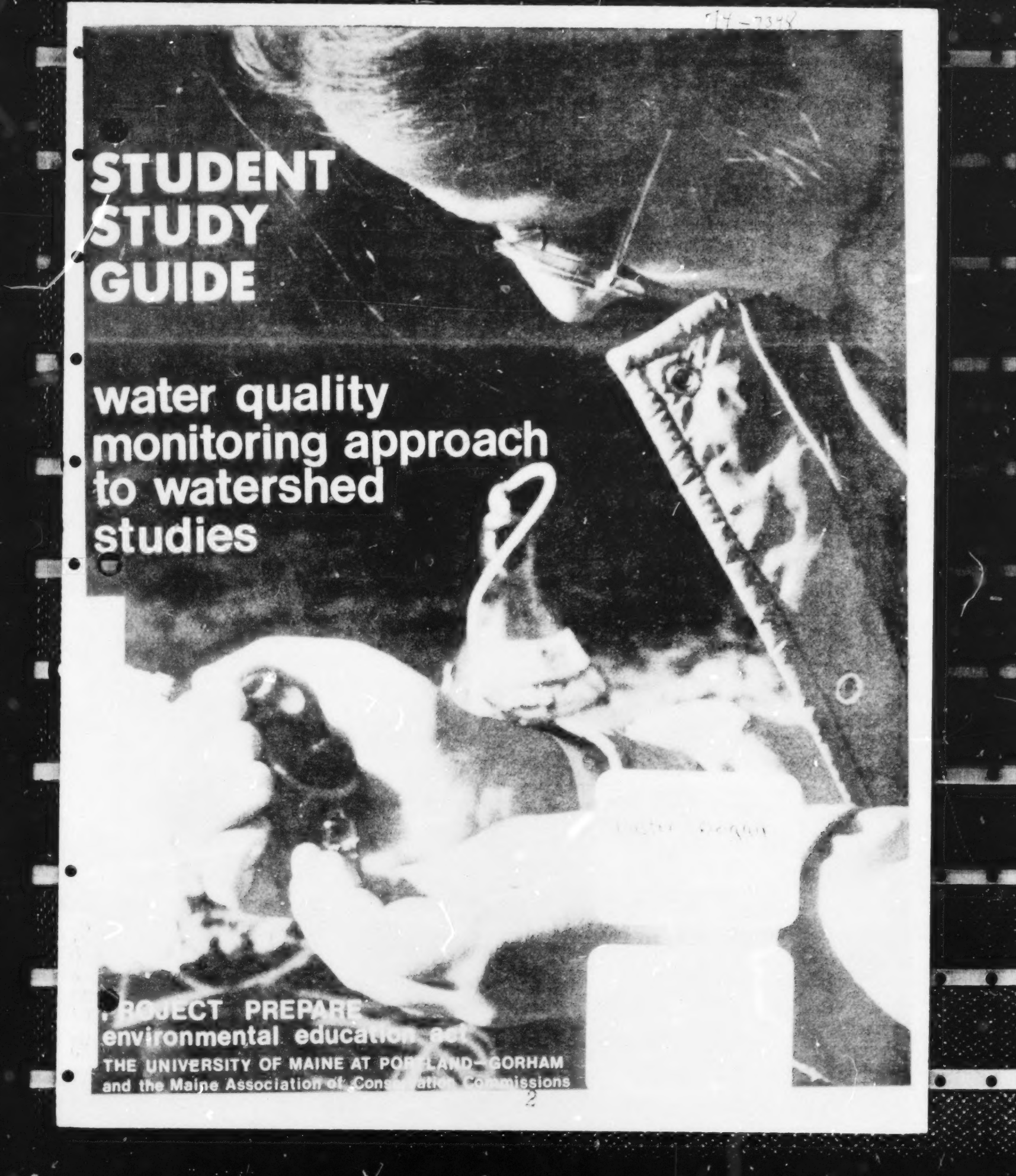
STUDENT
STUDY
GUIDE
water quality
monitoring approach
to watershed
studies
PROJECT PREPARE
environmental education
THE UNIVERSITY OF MAINE AT PORTLAND-GORHAM
and the Maine Association of Conservation Commissions

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STUDENT STUDY GUIDE

WATER QUALITY MONITORING APPROACH
to
WATERSHED STUDIES

Prepared by:

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PRESUMPSCOT RIVER EDUCATION PROJECT

1975

THE UNIVERSITY OF MAINE AT PORTLAND-GORHAM
and the
Maine Association of Conservation Commissions

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INTRODUCTION

This student study guide to water quality monitoring is designed for both independent and class study. The procedures outlined are suitable for senior high school and college undergraduate students.

At the secondary school level it can be the basis for a unit in a science course. At the undergraduate college level, it provides an outline of activities for which students could contract as part of an environmental education or science course.

In particular, this guide can be of use in applying science concepts and skills to helping students identify and resolve water and land environmental problems. The guide stresses first-hand studies as well as classroom experiences. Through these field tested and proven activities science can become interrelated with other disciplines in the curriculum.

OBJECTIVES

The student will be able to:

1. (Skill) Topographic Mapping

   Draw on a topographic map the physical boundaries of a river or stream watershed.

2. (Cognitive) Ecological Factors

   Describe in writing and map the significant characteristics of the ecological factors which contribute to the stability of watershed natural ecosystems.

3. (Cognitive) Water Problems

   Describe in writing common water quality problems including their characteristics, causes and solutions.

4. (Cognitive) Technological, Political, Economic and Social Factors

   Describe in writing the significant technological, economic, political and social factors to consider in water quality management. These should include reference to laws at all levels, government agencies and institutional structures responsible for policies and managing programs for maintaining water quality.

5. (Cognitive) Watershed Selection

   Select a small stream watershed for study containing at least one water quality problem.

6. (Cognitive) Water Quality Parameters

   Describe important chemical, physical and biological parameters involved in water quality determination.

7. (Cognitive) Monitoring Site Selection

   Select a water quality monitoring site.

8. (Cognitive) Parameter Selection

   Select appropriate parameters to monitor.

9. (Skill) Monitoring

Carry out skillfully and accurately water quality monitoring methods using equipment correctly.

10. (Cognitive) Analysis and Reporting

Record, interpret and report on the significance of the monitoring data.

11. (Cognitive) Alternative Solutions

Suggest alternative solutions to the selected water quality problem with recommendations for a solution or solutions.

ACTIVITIES

OBJECTIVE 1: Topographic Mapping

Background Information:

A watershed by definition is a land area from which water drains to a given point. How big a watershed is and the shape of it depends on the topography or the rise and fall and shape of the land. When water falls on a mountain some of it will flow down one slope and some down another. The point on the mountain where water may go in either direction is called a divide. This is where the water is divided into different directions of flow. The topography or shape of the land of a region determines where the divides are and, therefore, where the watershed boundaries are located.

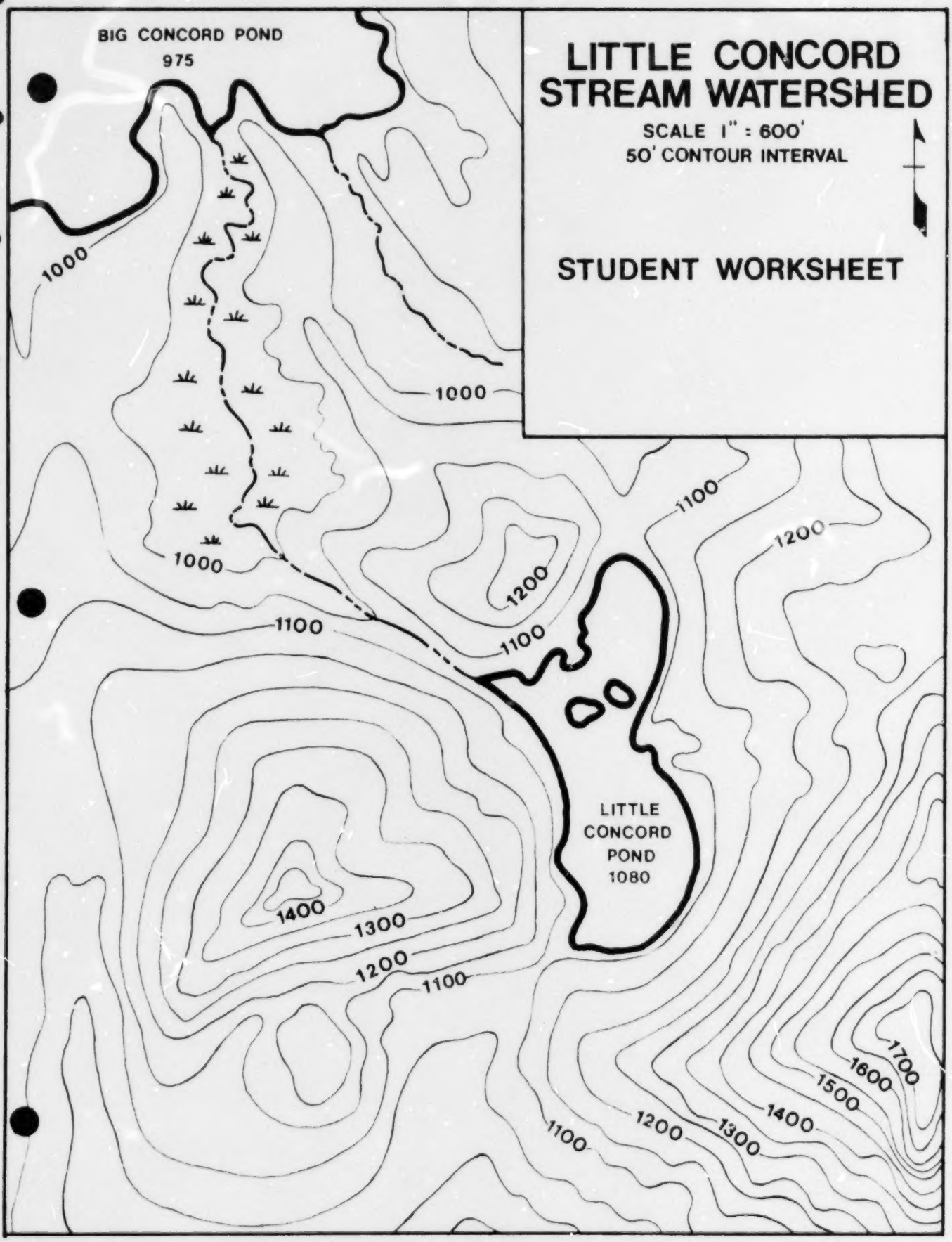
Topography is measured and mapped by topographic lines. A topographic line is a line which follows the contour of the land and all points on that line are at the same elevation. The distance between topographic lines (height in elevation) is called the contour interval. This is a distance in height such as 50 feet or 20 feet.

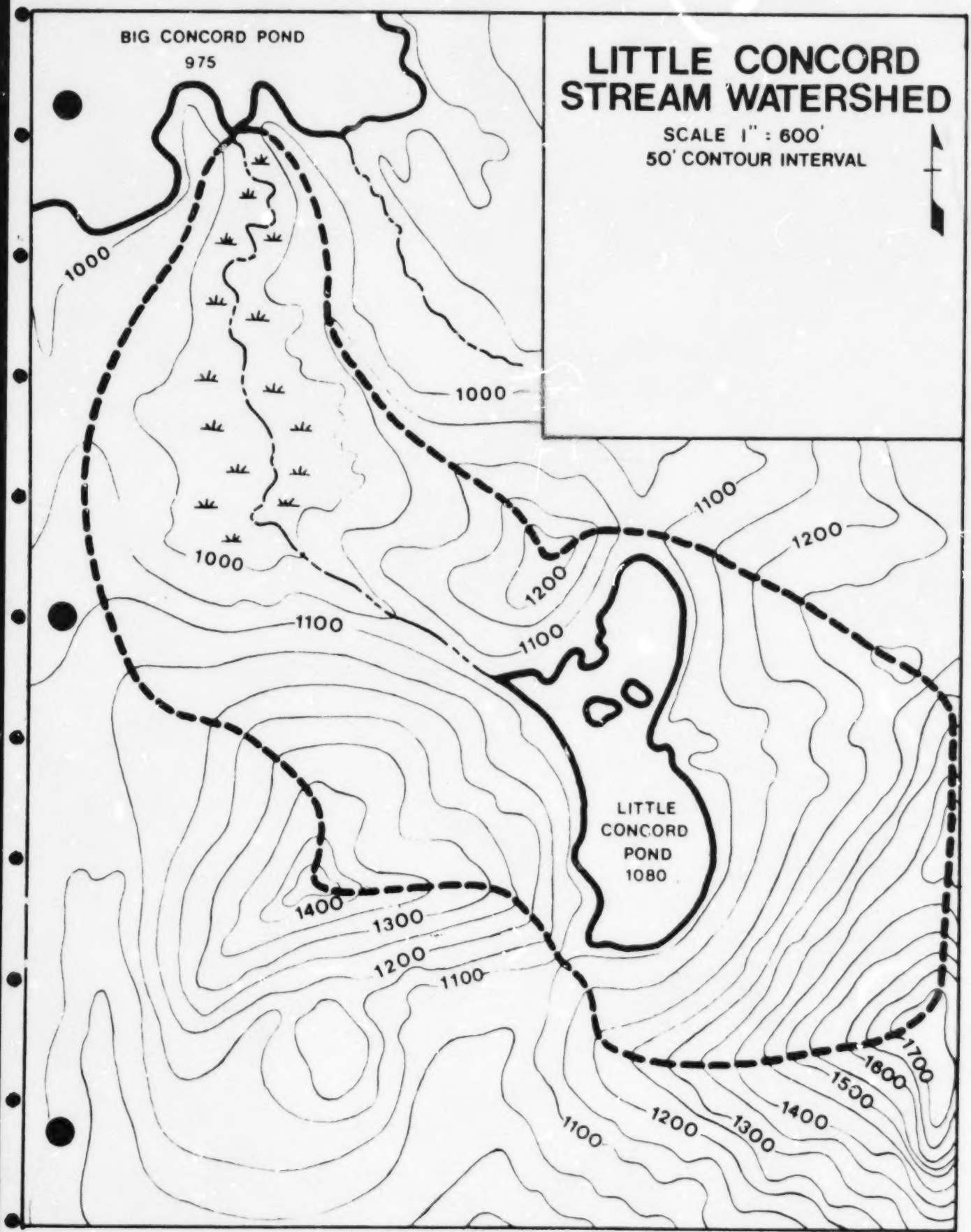
Study References:

Topographic Maps. U. S. Geological Survey.

Activities:

On the Student Worksheet for Little Concord Stream Watershed draw the boundaries of the watershed. Try to visualize the elevations and shapes of contours while looking at the topographic lines. The worksheet and solution sheet are on the following two pages.


BIG CONCORD POND
975
LITTLE CONCORD STREAM WATERSHED
SCALE 1" = 600'
50' CONTOUR INTERVAL
STUDENT WORKSHEET
1000
1000
1000
1100
1100
1100
1200
1200
1200
1300
1300
1400
1400
1500
1600
1700
LITTLE CONCORD POND
1080


BIG CONCORD POND
975
LITTLE CONCORD STREAM WATERSHED
SCALE 1" : 600'
50' CONTOUR INTERVAL
1000
1000
1000
1100
1100
1100
1200
1200
1200
1300
1300
1400
1400
1500
1600
1700
LITTLE CONCORD POND
1080

3b

OBJECTIVE 2: Ecological Factors

Background Information:

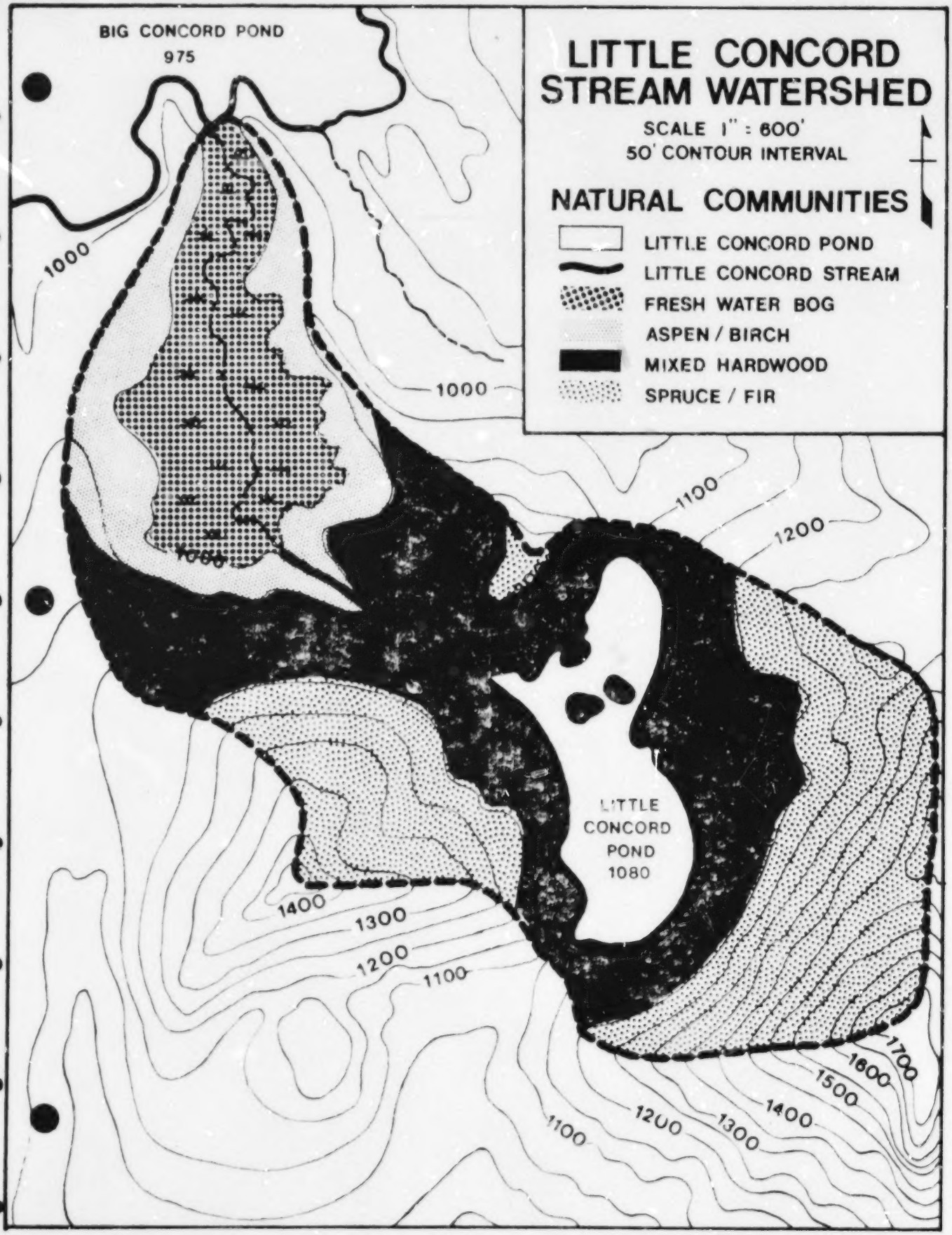
The natural ecosystem of a watershed is composed of communities. A community is made up of plant and animal populations in a distinct area or habitat. There are six (6) different communities in the Little Concord Stream Watershed. A brief description of each follows. Refer to the map on the following page for their size, shape and location.

1) Little Concord Pond is a 26 acre lake with a maximum depth of 56 feet. It is clear and cold. The primary food chain is plankton (small plants and animals), minnows, smelts, brook trout and pickerel. Since it is a young lake, the bottom is gravel with little sedimentation. There is yet little indication of its slow change to becoming a bog.

2) Little Concord Stream flows out of the lake and into Big Concord Pond. It is quite small. It is young and fast flowing where it leaves the pond, but slows down and meanders when it reaches the fresh water bog. The cooler waters are near the lake and they become warmer in the bog. Oxygen content is fairly high, particularly at the end of its drop to the bog. It is suitable habitat for trout in the upper reaches and chubs and suckers in the lower.

3) The Fresh Water Bog is a low wet area of approximately 40 acres in size. The water is warmer and it is flooded annually. It has a high variety of different kinds of plants and animals. Plants include cattails, rushes, grasses, sedges, pitcher plants, skunk cabbage, buttercups, tamarack and alders. Animal species include muskrat, mink, red-wing blackbird, moose, deer, great blue heron, bittern, raccoon, and tree swallows. It is a gathering place for many species of wildlife.

4) The Aspen-Birch community surrounds the bog. These trees have shallow roots and large water requirements making this area with the higher water table an ideal location for them. This area represents a later stage of succession than the fresh water bog.


BIG CONCORD POND
975
LITTLE CONCORD STREAM WATERSHED
SCALE 1" = 600'
50' CONTOUR INTERVAL
NATURAL COMMUNITIES
LITTLE CONCORD POND
LITTLE CONCORD STREAM
FRESH WATER BOG
ASPEN / BIRCH
MIXED HARDWOOD
SPRUCE / FIR
1000
1000
1100
1200
LITTLE CONCORD POND 1080
1400
1300
1200
1100
1700
1600
1500
1400
1300
1200
1100

5) The Mixed Hardwood community covers a large portion of the watershed. It contains mature trees and is quite densely wooded. Species include maple, beech, and birch as well as some scattered white pine and hemlock. It contains the animal species of the many upland hardwood forests. These include ruffed grouse, white-tailed deer, porcupine and chickadees.

6) The Spruce Fir communities are located towards the tops of the mountains. Both the climate and the soil conditions here favor this type forest. The many rocky outcrops and ledges also favor those plants common to early successional stages. These include lichens, mosses and pioneer grasses. Animal populations are less numerous here.

Rating Factors for Watershed Stability

Stability here refers to the ability of a natural ecosystem to resist changes which would be detrimental to it or would destroy it. The existing state of the following seven factors contribute to determining the stability of a natural ecosystem. These factors are:

Slope, soil depth to bedrock, erodibility, soil fertility, ground cover, species diversity, and populations.

In nature, each factor occurs in a variety of conditions which enable it to contribute toward a high, medium, or low stability. Each factor can be evaluated and the values for all factors combined to give a composite picture of stability in the watershed. These are described below and presented in map form.

1) Slope

Slope is the amount of rise or fall of the land for a given distance. It is usually expressed as a percentage. For example, for a 10% slope there is a 10 foot rise or fall over a 100 foot distance horizontally. Sometimes slope is expressed in degrees which refer to the angle made by the horizontal plane and the rise. For example,

a 45° angle slope is ½ way between a straight up and down cliff and perfectly flat land. This would be a 100% slope. On the overlay - anything over 25% slope which is a 25 foot rise over a 100 foot run (coded dark) is considered to be most unstable and very sensitive to change. A 15-25% slope (coded light grey) is considered to be less sensitive to change but more sensitive than those slopes which are between 0-15% (coded white).

Discussion Questions:

1. Why is a steep slope more sensitive to change?

2. Why is the 0-15% slope considered to be less sensitive to change?

3. What natural factors would make a steep slope less sensitive to change?

2) Soil Depth to Bedrock

The depth of the soil to bedrock can also affect the stability of a natural ecosystem. This simply means how deep the soil in the weathered rock material is. This material provides the basis for plant and animal life. Therefore, the amount available is very important. Ten inches or less of soil to bedrock would be considered very shallow and this condition is more vulnerable to change. It is also very likely a younger soil. On the overlay it is coded dark. Up to 40" in depth to bedrock could be considered a medium depth soil. Code it light grey. This soil is more plentiful and is conducive to a greater abundance of life. Over 40" of soil to bedrock would be considered deep. As far as amount is concerned, it promotes the greatest abundance of life. It is coded white.

Discussion Questions:

1. What are some of the reasons why shallow soil is less likely to contribute to stability?

2. On what type of terrain would you expect to find shallow soil?

3. What forces would cause deeper soils?

3) Erodibility

Erodibility is the soil's susceptibility to being removed from one place to another. It is based on the interrelationship of several factors among which are soil texture and slope. A high erodibility rating (coded dark) indicates that soil is easily lost because the texture is fine and the slope is steep. A medium erodibility rating (coded light grey) indicates a soil that is coarser and/or on a less steep slope. A low erodibility rating indicates a situation where the soil is least likely to be lost and reflects coarse soil texture and/or little slope. The coarser soils are more permeable to water and, therefore, less subject to the run-off which creates erosion. This would give a low erodibility (coded white) if the slope is not great. It should be noted that fine textured soils could be given a low erodibility rating if there is no slope.

Discussion Questions:

1. What other factors besides those above do you think would affect the erodibility rating?

2. Why is erodibility an important factor to consider in natural ecosystem stability?

3. How would a lot of living organisms affect erodibility?

4. What determines the texture of soil?

4) Soil Fertility

Soil fertility refers to the availability of nutrients for the primary producers (plants). Major nutrients in the soil include potassium, phosphates, and nitrogen. It is the pH or acidity of the soil which determines how available the nutrients which are present will be for plant consumption. If a soil is too acidic (low pH) or too alkaline (high pH) it will lock up the nutrients for most plants. The majority of plants prefer a pH which is slightly more alkaline than it is acidic. This soil is considered to be of high fertility and is coded white. A soil which is slightly more acidic or alkaline is considered to have medium fertility and is coded light grey. A soil which is highly acidic or alkaline and which also may have nutrients missing is considered to

be of low fertility and is coded dark.

Discussion Questions:

1. How does high soil fertility lead to a greater stability in the natural ecosystem?

2. Why would some areas have higher fertility than others?

3. How can one tell soil fertility by looking over the landscape?

5) Ground Cover

Ground cover refers to the amount of surface area which is covered with vegetation. It gives an indication of how efficient an area is in capturing the sun's energy. Included in the concept is the density of vegetation and the number of levels of light capturing leaves. The greater the density, the higher the number of levels, and the greater the surface area covered, the higher will be the rating of stability for that location (coded white). A medium rating (light grey) would result from less dense vegetation, fewer levels with light capturing leaves, and a lesser surface area covered. Those areas coded dark have less ability to capture the sun's energy when compared to the others.

Discussion Questions:

1. What other benefits result from a high percentage of ground cover?

2. What factors contribute to differences in ground cover?

3. What would you look for when determining the ground cover rating?

6) Species Diversity

Species diversity relates to the number of different kinds of plants and animals found in a given area. A highly diverse area would contain many different species of plants, therefore, animals. An area with high species

diversity (coded white) is more likely to be stable because its richness of species allows one to be eliminated without removing them all. For example, a field containing one type of grain can be a place where there is a variety of animal life. Should all the grain be attacked by a certain type of beetle and die, all other species must find another area or themselves, die. Diversity allows alternatives and keeps the pressure off any one species. An area coded light grey contains fewer species although it may contain the same number of individuals. An area coded dark would contain fewer species still and may have several populations or even one population (like the corn field) predominant.

Discussion Questions:

1. What does the Dutch Elm Disease problem tell us about diversity?

2. What might cause diversity to drop?

3. What is the effect of the diversity of plants on the diversity of animals?

7) Populations

Populations refers to the number of individuals in each species. For any given place and situation there is an optimum number of individuals for each species population. This optimum population number represents a species which is contributing to the total health of the ecosystem through its role in the food web. This results in efficient use of energy and cycling of matter. If a population of a species has too few individuals, the species will not reproduce itself and will die out. On the other hand, if a population of a species has too many individuals, or an overpopulation, this may lead to:

1. other species being crowded out,
2. certain foods becoming scarce,
3. disease running rampant, and
4. niches and habitats disappearing.

On the map, areas within the watershed having optimum population conditions are coded white. Areas with less desirable population conditions are coded light grey and areas with undesirable population conditions are coded dark.

Discussion Questions:

1. What could happen when one species becomes too numerous for an area?

2. What could cause over population?

3. What could cause underpopulation?

Study References:

Ecology Primer. pp. 1 - 111.

A Curriculum Activities Guide to Water Pollution and Environmental Studies, Vol. I. pp. 1-1 to 1-9, 3-1 to 3-61.

Activity:

Prepare an overlay of each of the factor maps, e.g., slope, soil depth to bedrock, etc. This may be done on a thermal copier or by tracing by hand onto acetate with a marker and using crosshatching to indicate shading. Combine the overlays and study them in front of a well lighted window, on a light table or projected on an overhead projector. The picture obtained is the overall stability of the watershed. Those areas which are the darkest are the least stable and, therefore, the most sensitive to change. Those areas which are lightest are the most stable or most resistant to change. Consider the following questions:

1. According to the overlays, where would be the place to put your cabin that would have the least detrimental impact on the watershed?
How would you go about determining the best location?
What steps would you go through?

   The following are considered by many to be the important and logical steps to take:

   1) Determine what natural environmental features are most desirable for locating a cabin.

   2) Find out what effect a cabin would have on the natural features.

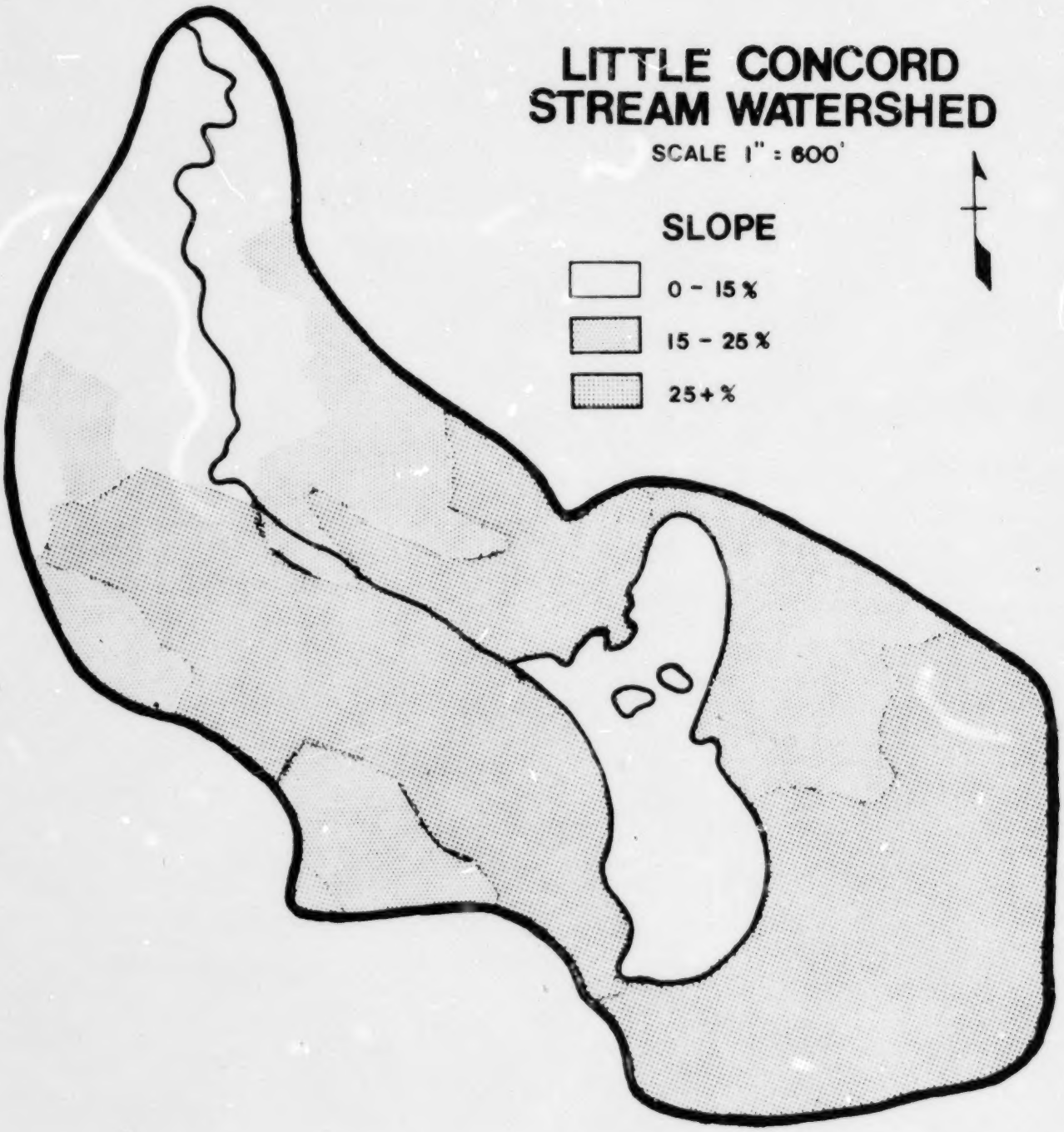
3) Determine the natural characteristics or features in a desired area and the location of potential sites.

4) Compare the known effects of a cabin with the characteristics of potential sites and select the site which would be the least damaged by the cabin.

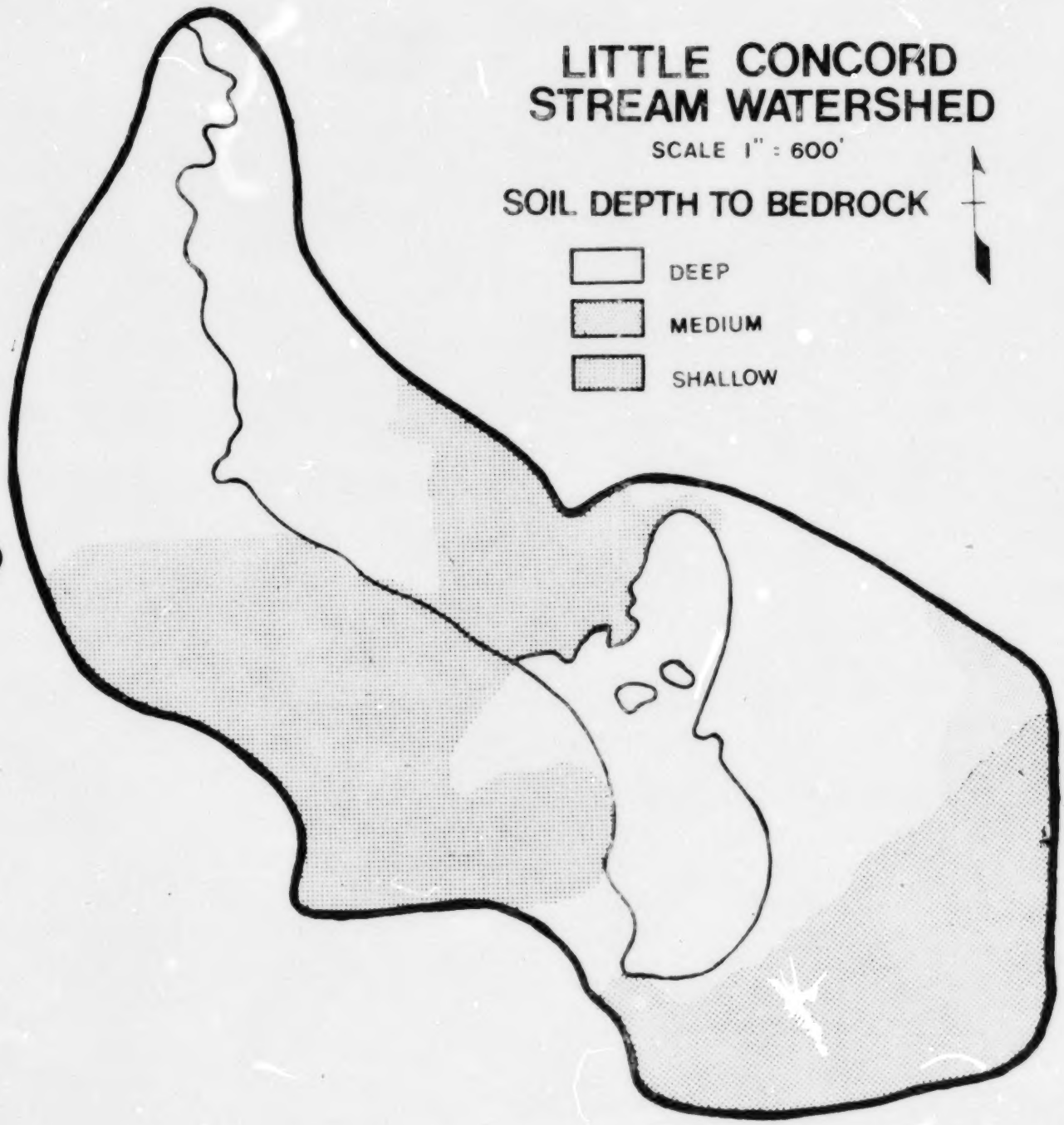
5) Call in experts to check your decision on a location.

2. If you had to design a road to cross the watershed, where would it go?

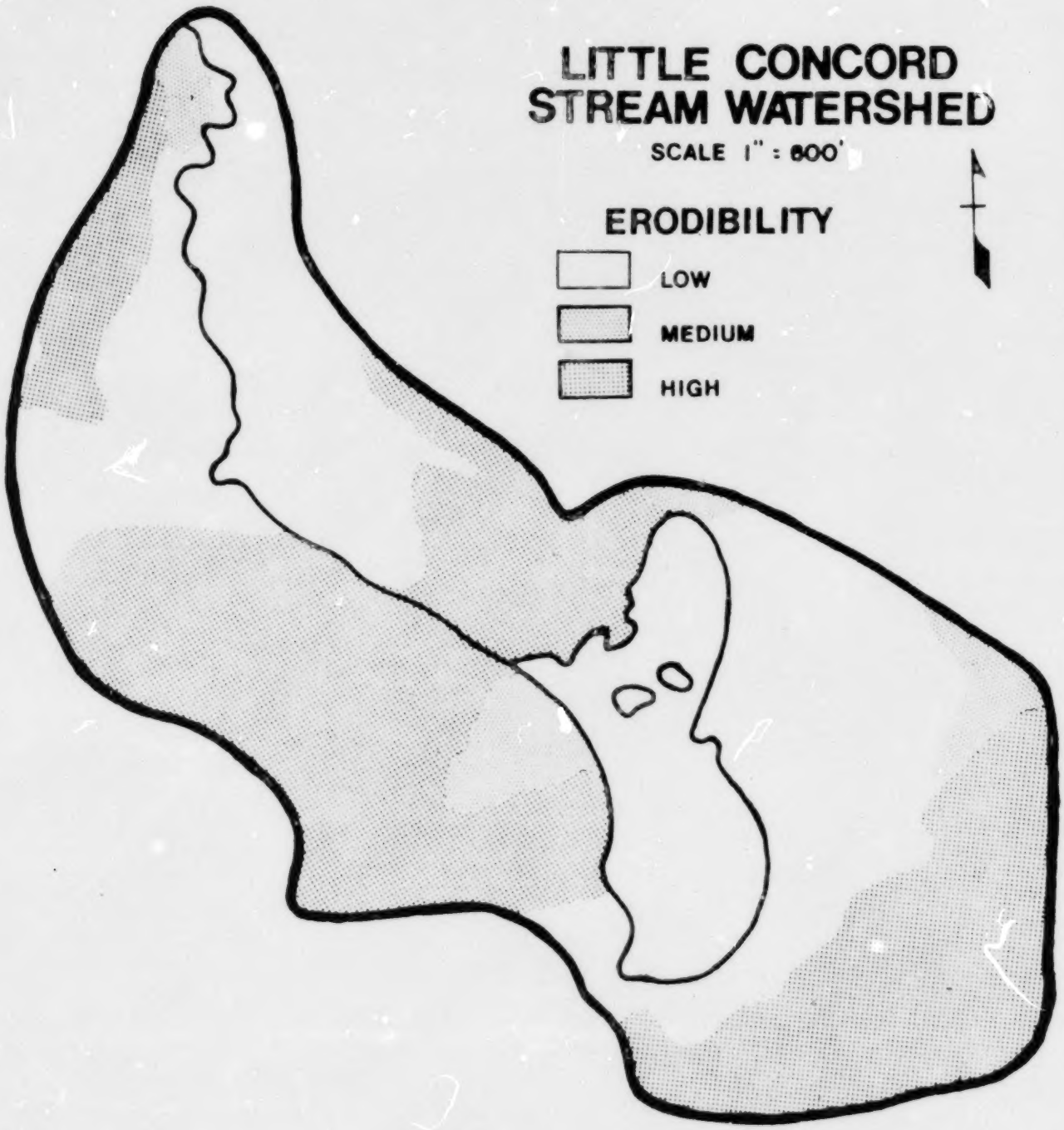
3. If you were zoning this watershed according to the three categories of "no development," "limited development" and "general development," where would each of these zones be?


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" = 600'
SLOPE
0 - 15 %
15 - 25 %
25+ %

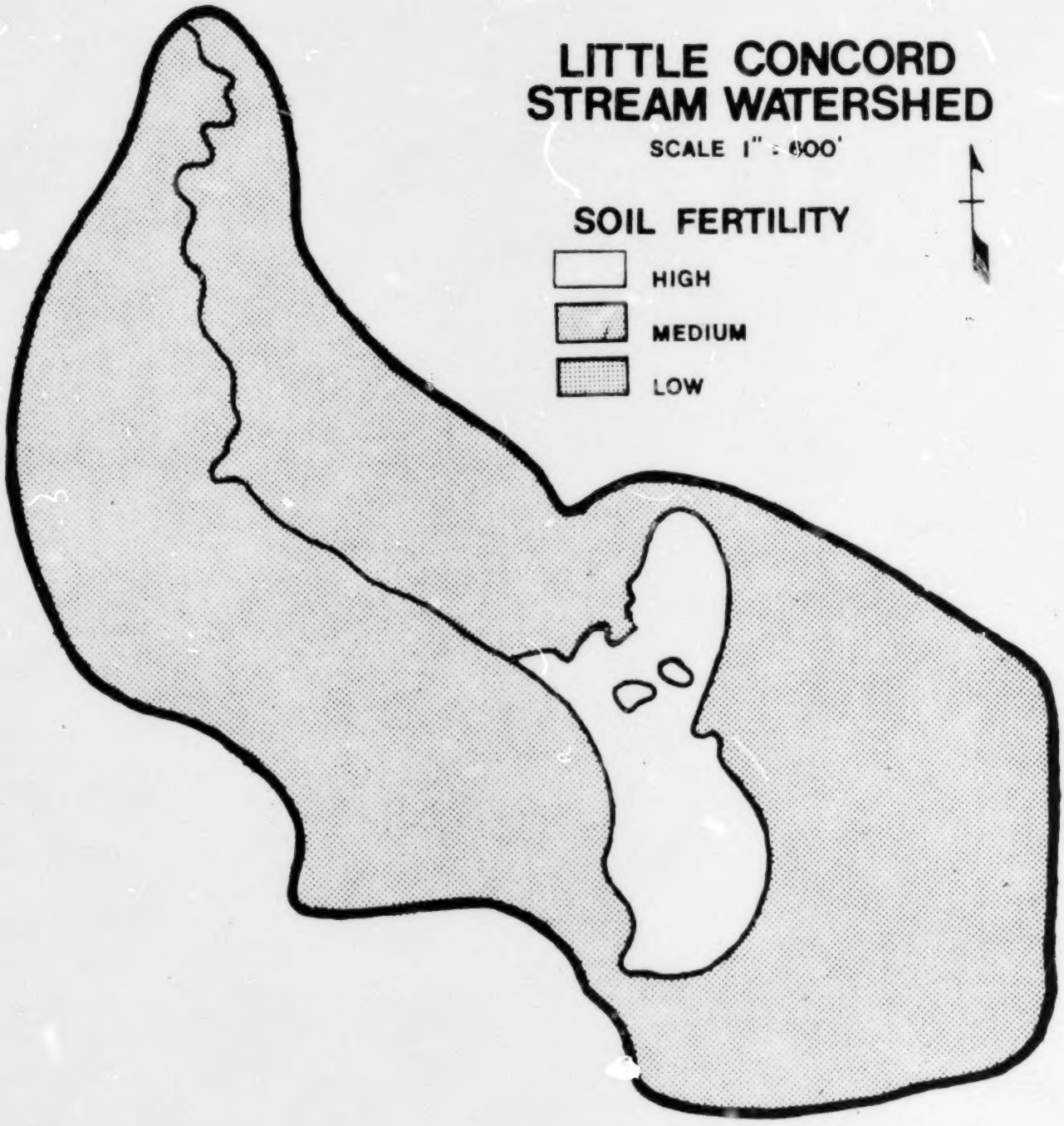
11a


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" : 600'
SOIL DEPTH TO BEDROCK
DEEP
MEDIUM
SHALLOW

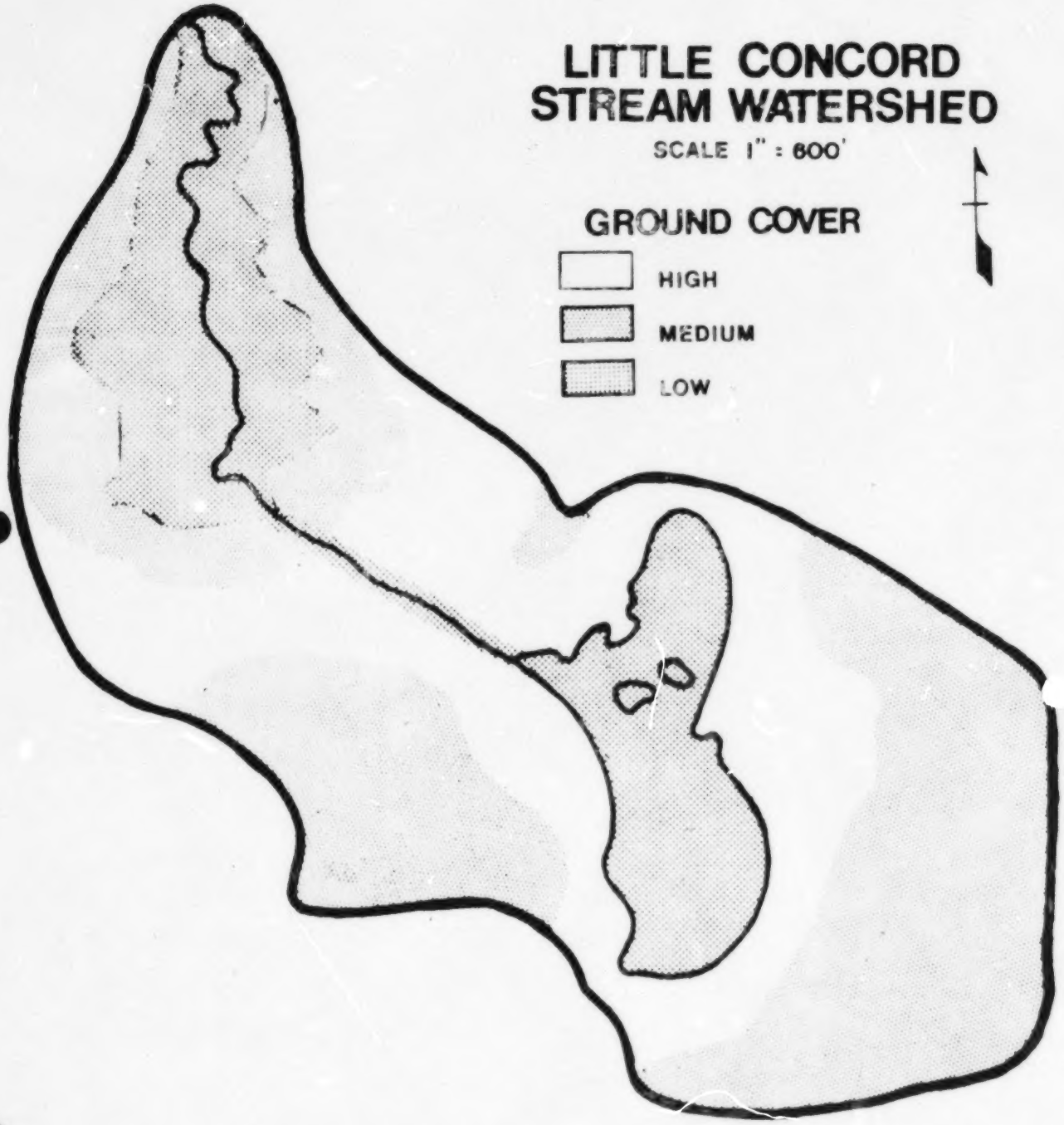
11b


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" : 600'
ERODIBILITY
LOW
MEDIUM
HIGH

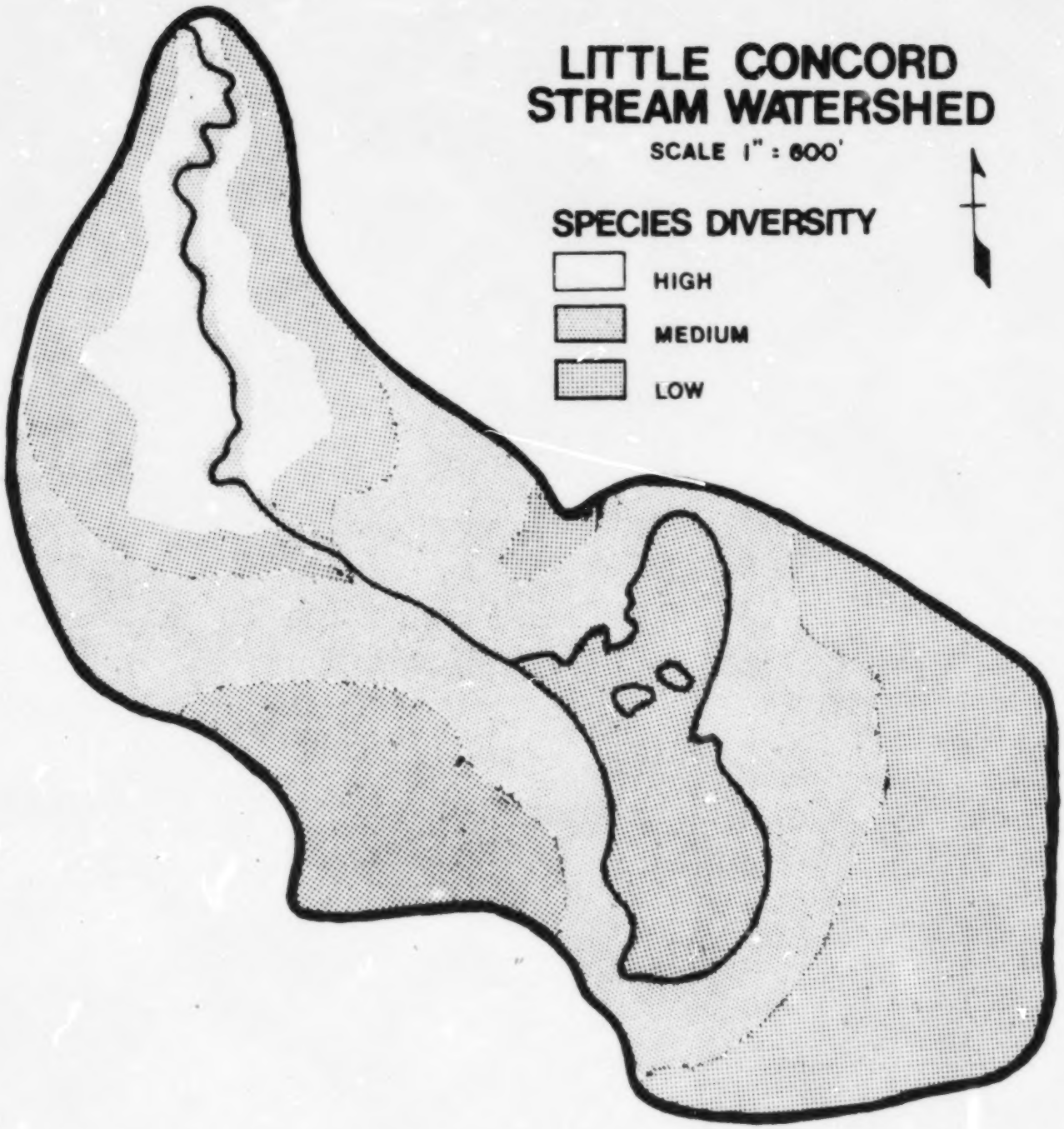
11c


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" = 600'
SOIL FERTILITY
HIGH
MEDIUM
LOW

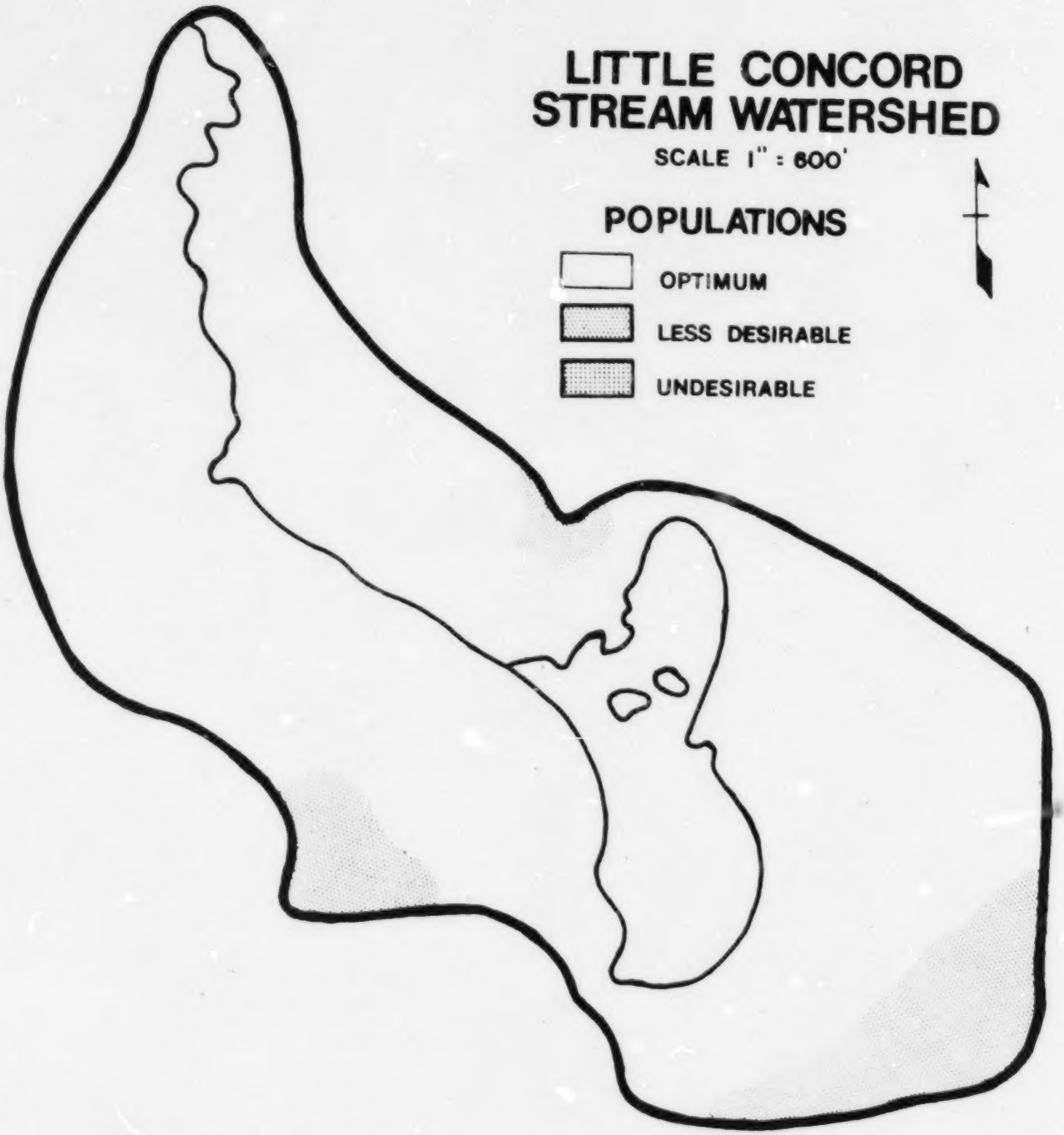
11d


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" : 600'
GROUND COVER
HIGH
MEDIUM
LOW

11e


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" : 600'
SPECIES DIVERSITY
HIGH
MEDIUM
LOW

11f


LITTLE CONCORD
STREAM WATERSHED
SCALE 1" : 600'
POPULATIONS
OPTIMUM
LESS DESIRABLE
UNDESIRABLE

11g

OBJECTIVE 3: Water Problems

Background Information:

Problems of water quality involve the chemical characteristics of water, e.g., dissolved oxygen, the physical characteristics, e.g., turbidity, and the biological characteristics, e.g., pathogenic bacteria. Sources of water pollution include domestic sewage, industrial wastes, agricultural pollutants, recreational activity by-products, highway and storm-water runoff and abnormal heat. Detrimental effects include damage to natural ecosystems, aesthetic deterioration, danger to human health and limitations to human activities. Solutions may be found in such areas as scientific and social research, technological applications, economic systems, political processes, institutional arrangements and education.

Study References:

The Nature of Water Pollution and Its Relevance to Maine.

Activities:

Read the information and reference above. Research other up-to-date sources and prepare a brief paper describing the common water quality problems in your area. Include their causes, effects and efforts to resolve them.

OBJECTIVE 4: Technological, Economic, Political & Social Factors

Background Information:

The resolution of water quality problems is often dependent on the success of a program which coordinates many institutions of human endeavor, both public and private. Technology - the development, organization and use of tools, machines, instruments, operational procedures, methods and techniques - is an essential component of programs to deal effectively with problems. The application of technology depends heavily upon economics - monetary incentives, financial costs and benefits, ability and willingness to pay, etc. It takes policies, laws,

and regulations to bring about and direct the abatement of water pollution through technology and economic systems. It is through the political process that priorities are set, decisions made and laws and regulations established to allocate the resources needed to solve problems. Finally, these processes must be sensitive to human needs and conditions - the social factors involved.

Study References:

A Curriculum Activities Guide to Water Pollution and Environmental Studies. p. 4-1 to 4-4.

The Nature of Water Pollution and Its Relevance to Maine

Activities:

Choose one of the following activities in A Curriculum Guide to Water Pollution and Environmental Studies.

1. State and Local Government Organization, pp.4-9 to 4-16.
2. State Government Model, pp. 4-17 to 4-21.
3. Anti-Pollution Laws, pp. 4-22 to 4-27.
4. Investigation of Local Water Anti-Pollution Programs, pp. 4-28 to 4-38.

OBJECTIVE 5: Watershed Selection

Background Information:

Watersheds vary in size according to the drainage areas of the streams and rivers involved. The ecological characteristics within a watershed, e.g., type of soil and vegetative cover, as well as human activities influence the nature and extent of water quality problems present.

Study References:

1. Studies and reports on streams in your local area.
2. Topographic USGS maps, aerial photos, etc.

Activities:

Review reports, maps and other available documents describing the watershed characteristics of streams in your area. Select a small stream watershed for further study according to the following criteria:

1. The suspected presence of at least one water quality problem.
2. A size which may be surveyed easily first-hand.
3. Close-by, within easy driving or walking distance.

OBJECTIVE 6: Water Quality Parameters

Background Information:

In determining the quality of water there are many parameters which can be investigated. When tests are repeated over time it is called monitoring. It is through monitoring that changes in parameters and, therefore, water quality can be detected. Common parameters which are investigated in streams are: stream flow, water temperature, pH, turbidity, dissolved oxygen (DO), and total coliform.

Study References:

1. Environmental Pollution, pp. 22-88.

2. A Curriculum Activities Guide to Water Pollution and Environmental Studies, Vol. II, Appendix I, Water Quality Parameters, pp. A1-1 to A1-239.

Activities:

Read several references on water quality parameters and describe in writing, ten which are most significant as indicators of pollution. Describe each parameter and its value as an indicator.

OBJECTIVE 7: Monitoring Site Selection

Background Information:

The selection of a monitoring site should be based upon consideration of the following factors:

1. The need for data,
2. Likelihood of detecting any existing pollution,
3. Ease of access and sampling in all kinds of weather, and
4. Safety.

On a stream the site could be immediately below a suspected source of pollution. On a lake it is recommended that the site be at the deepest point.

Study References:

A Curriculum Activities Guide to Water Pollution and Environmental Studies. pp. 2-11; 2-26 to 2-30.

Activities:

Select a monitoring site on the stream just below a suspected source of pollution. Pinpoint the site on a map and describe the site and reasons for its selection.

OBJECTIVE 8: Parameter Selection

Background Information:

The selection of parameters to investigate is critical to the success and usefulness of a monitoring project. Generally, due to constraints of time, money, equipment and expertise, only a few are selected. The kind of pollution present also influences the decision. For example, in the case of human waste, coliform bacteriological tests are run to determine the probability of the presence of pathogenic organisms.

Quite likely a student monitoring program would serve to augment data being collected by an organization or state agency,

such as the Department of Environmental Protection. If such is the case, then assistance should be sought to determine data needs.

Study References:

A Curriculum Activities Guide to Water Pollution and Environmental Studies, Vol II. Appendix 2, pp. A2-1 to A2-5; Appendix 3, pp. A3-1 to A3-4.

Activities:

Select parameters to monitor considering the criteria discussed above. Describe briefly the reasons for the selection of each parameter.

OBJECTIVE 9: Monitoring

Background Information:

Monitoring means to make repeated tests or investigations over time, usually on a regular or periodic basis. Become familiar with monitoring methods and procedures for the parameters and methods chosen and the equipment available.

Study References:

1. A Curriculum Activities Guide to Water Pollution and Environmental Studies, Vol. II. Appendix 1, pp. A1-1 to A1-239.

2. Environmental Pollution. pp. 166-200.

Activities:

Carry out a monitoring program by collecting data at a site on a regular basis, for example, once every week or every two weeks. It is usually important to carry out the field sampling during the same time of day and to replicate the

procedures as closely as possible. For further information refer to A Curriculum Activities Guide to Water Pollution and Environmental Studies, Vol I; (1) Community Survey, pp. 2-11 to 2-20 and (2) Pollution and Recovery, pp. 2-26 to 2-30.

OBJECTIVE 10: Analysis and Reporting

Background Information:

The keeping of accurate, complete and neat records in a logical format is essential to analysis and interpretation. Reporting should be in concise terms which are easily understood. See Appendices I and II for sample data forms and data tabulation.

Activities:

Maintain neat and accurate records of all data collected. Write a report summarizing the findings. Give conclusions and the significance of the individual and overall results.

OBJECTIVE 11: Alternative Solutions

Background Information:

Based upon the findings of a monitoring program, alternative solutions are often generated to resolve problems. These generally take into account the technological, economic, political and social factors studied under Objective Four. After careful consideration of the consequences of each possible solution, a solution or combination of solutions may be selected. This is followed by:

1) the development of a plan of action,
2) its implementation and
3) evaluation of results.

Activities:

Develop and describe two or three alternative solutions to the problem investigated. Select one and discuss the reasons for its selection.

EVALUATION

Evaluation may be based upon a written report covering each of the eleven objectives. Criteria for evaluation will include:

Completeness

Accuracy

Readability and neatness

Completion within scheduled time period.

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607 Boylston Street
BOSTON, MASS. 02116

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2. The Facts of Life . . . or The Birds and Bees of Water

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MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION
State House
AUGUSTA, MAINE 04333

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2. Protecting Your Lake - A Citizen's Guide to the Great Ponds Act

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NATIONAL ENVIRONMENTAL RESEARCH CENTER
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CINCINNATI, OHIO 45268

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2. Proposed Criteria for Water Quality Vol. I and II, October 1973

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5. Methods and Practices for Controlling Water Pollution from Agricultural Non-Point Sources

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1015 18th Street, N. W.
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PRENTICE HALL
ENGLEWOOD CLIFFS, NEW JERSEY 07632

Environmental Pollution. William A. Andrews, Ed.

U. S. GEOLOGICAL SURVEY
Map Information Office
WASHINGTON, D. C. 20242

Map Information

HACH CHEMICAL COMPANY
P. O. Box 907
AMES, IOWA 50010

Handbooks
Equipment

APPENDIX - I

SAMPLE WATER MONITORING

REPORT FORMS

INLAND WATER ANALYSIS RECORD

PROJECT PREPARE

STATION NO. _____ LOCATION: _____

WATERWAY: _____

MAJOR WATERSHED: _____ NATURE SAMPLING POINT: _____

MINOR WATERSHED: _____

WATERWAY CONDITION: _____

DATE	WEATHER	TEMP. AIR	TEMP. °C WATER	DISSOLVED OXYGEN		B.O.D. P.P.M.	pH	TOTAL ACIDITY	TOTAL ALKALINITY	COLOR	TURBIDITY	B-Coli M.P.N.	
				P.P.M.	% SAT.								

I-1

PROJECT PREPARE

Survey of _____

Date _____
Weather _____
Temperature °C _____
Inspector _____

Station Number	Temp. °C Water	Dissolved Oxygen		B.O.D. PPM	PH	Alkalinity & Acidity	Color Turbidity	B. Coli M.P.N.
		PPM	%Sat.			phen. M.O.	PPM	

EIC-30

APPENDIX II

REPORT OF A SECONDARY

SCHOOL MONITORING PROGRAM

Charles Sendzik, Science Teacher
GORHAM HIGH SCHOOL
Gorham, Maine

YEAR ACTIVITIES

in

WATER QUALITY MONITORING PROGRAM

Three freshmen science students (Charles Wyman, Terry Nason, and Jimmy Costa) were selected to participate in the program, along with the earth science instructor (Charles Sendzik) at the high school. Credit must be given to all those that had anything to do with the training program we attended during October, 1974, at UMPG. I have participated in other types of workshops, but never gaining as much as at this one. The training that we received from the visiting students and instructors was tremendous. The success of any program is a good beginning.

There was a short waiting period from the time of our training sessions until our equipment arrived and we were using it. After a few trial tests were run, we established a regular sampling/testing schedule of every other Wednesday starting December 18, 1974, which has continued through the end of the school year.

It took several trail tests before we established a sample dilution that would give us good results. Most of the total coliform bacteria tests were done at a ten to one dilution. Most frequently we also ran a one hundred to one dilution test for comparison. In most all tests the results were nearly the same. We used this as an indication of the accuracy of our testing procedures.

We did encounter one problem with culturing the bacteria. Until we started using an electric heating oven set at about 37°C, we were not having any results. Tests that would be taken Wednesday at the close of school would not show much

bacterial growth even as late as Friday. We concluded that the low classroom temperatures were a factor. Upon using the oven, satisfactory results were obtained in twenty-four hours. The only other problems were very minor, such as climbing over snowbanks, walking in waist-deep snow, and chopping through several inches of ice. All of our tests were conducted in the classroom as we were only ten minutes maximum from the test sites.

As we went through each test, comparisons were made with previous tests to note any changes and to perhaps suggest reasons for the changing conditions.

Gorham participated in all the follow-up meetings and activities, and we found them to be most informative and meaningful.

One of the most important aspects of the entire program was the realization that the information that we were obtaining was not difficult to attain, but was instead a simple, precise, procedural process that should make it easy for students to realize that one of the most important things to life - the environment - can be monitored and studied, without years of study and lots of costly equipment. Perhaps this can be an incentive to many young people to look at career potentials in the field of the environment.

GORHAM TESTING STATIONS

STATION NUMBER I Mosher Road Bridge, Little River, Gorham

Width of stream: some twenty-five to thirty feet

Depth of stream: some four to five feet

Current: slow to moderate at testing site

Nearby upstream conditions: generally glacial moraine - fairly level, southern bank of river mostly mixed forest, northern bank mostly cleared fields with individual dwellings

Source: water originates from several small tributaries over a length of about six miles of Gorham countryside

Destination: water enters the Presumpscot about one half mile below testing site

STATION NUMBER II Brandy Brook, Flaggy Meadow Road, Gorham

Width: varies from two to six feet

Depth: ten inches maximum at testing site, mostly four to six inches

Current: moderate at testing site because of slope, many ripples with some quiet pools, volume is very small

Nearby upstream conditions: generally low lying, swampy area, mostly brush-pasture type of land, dairy farm on one side

Source: flow of water comes from about a half mile of swampy area

Destination: water enters the Little River a little over a mile from the test site

DATA SHEET

Little River
Mosher Road Bridge, Gorham

DATE Collecting Time, 2:30	WEATHER	STREAM FLOW	AIR TEMP	WATER TEMP	pH	D.O. Mg/L	TOTAL COLIFORM per 100 ml	NOTED CONDITIONS
12/18/74	Fair	Normal	5°C	3°C	7.5	11	870	---
01/08/75	Partly cloudy	Normal	4°C	0°C	7.0	12	720	1" of ice
01/22/75	Mostly cloudy	Normal	3°C	0°C	7.0	11	650	1" of ice
02/12/75	Cloudy snow	Low	-6°C	0°C	7.0	8	530	6" of ice
02/26/75	Sunny	High recent rains	4°C	0°C	6.8	13	640	Spring condition run off
03/12/75	Cloudy flurries	Low	2°C	0°C	7.2	9	400	Ice covered - some open water
03/26/75	Cloudy	Normal	2°C	2°C	7.0	11	800	Completely free of ice - very turbid
04/09/75	Mostly cloudy	Normal	6°C	4°C	7.0	12	270	Very turbid - receding from recent run off
04/30/75	Sunny	Normal	16°C	8°C	7.8	12	194	---
05/12/75	Sunny	Normal	20°C	16°C	8.8 (7.8)*	12 (9.2)*	220	---
05/14/75	Partly cloudy	Normal	23°C	18°C	8.5	11	260	---
05/28/75	Sunny	Normal	27°C	19°C	8.5	11	175	---

*Results using DEP equipment

DATA SHEET

Brandy Brook
Flaggy Meadow Road, Gorham

DATE Collecting Time, 2:15	WEATHER	STREAM FLOW	AIR TEMP	WATER TEMP	pH	D.O. Mg/L	TOTAL COLIFORM per 100 ml	NOTED CONDITIONS
12/18/74	Sunny	Normal	7°C	3°C	7.8	11	70	---
01/08/75	Partly cloudy	Normal	4°C	0°C	7.2	12	84	Wood chips dumped into stream
01/22/75	Mostly cloudy	Normal	3°C	0°C	7.0	12	50	Nearly ice covered
02/12/75	Cloudy-snow	Low	-6°C	0°C	7.0	8	68	Ice covered
02/26/75	Sunny	High recent rains	6°C	.5°C	7.0	10	810	Spring conditions run off
03/12/75	Cloudy-flurries	Low	3°C	4°C	7.0	9	280	Low - free of ice
03/26/75	Cloudy	Normal	6°C	4°C	7.0	11	620	---
04/09/75	Mostly cloudy	Normal	10°C	8°C	7.0	11	100	---
04/30/75	Sunny	Normal	22°C	15°C	7.5	10	173	---
05/12/75	Sunny	Normal	26°C	18°C	8.0 (7.3)*	11 (9.0)*	128	---
05/14/75	Partly cloudy	Normal	27°C	21°C	8.0	10	106	---
05/28/75	Sunny	Normal	31°C	22°C	7.5	9	87	---

*Results using DEP equipment

STUDENT EVALUATIONS

During the last of May each student participant was asked to submit a short evaluation of their part in the program.

Charles Wyman: "I think it was a worthwhile project. It was fun and you met new people. I got a lot of experience out of it. It is a well working project. It would be nice to be able to continue it. I think it would be nice to get more people in it - like a class. In the future, if I had to use the equipment, I would be able to do it and know what I was doing."

Jimmy Costa: "I learned of tests I had not heard of, and how to do them. I learned that there was more going on about pollution in our area than I had thought. It gave me experience and opened me to a different branch of study. I enjoyed what I was able to do, and glad that I was a part of the program."

Terry Nason: "I enjoyed the project, and I also enjoyed the work and progress that was made. The project was very educational, and every time I went out testing water I learned something new. This is only part of what made the project interesting. Because I am concerned with the future and ecology, Project PREPARE became a means of gathering more information about the subjects. I don't know how I will use this knowledge in the future, but I am thankful that if I get an opportunity to use it again, that it will be there."

APPENDIX III

GLOSSARY OF

TERMS AND PROCEDURES

pH

pH is a measurement which reflects the instantaneous free hydrogen ion concentration in a water sample. Free hydrogen and hydroxide ions exist in equilibrium in all aqueous solutions. If these ions are present in equal amounts, the sample is described as neutral and has a pH value of 7. If the hydrogen ion concentration is less than the hydroxide ion concentration, the solution is said to be basic and has a pH value greater than 7. If the hydrogen ion concentration is greater than the hydroxide ion concentration, the solution is acidic and has a pH value less than 7.

acidic $(H+) > (OH-)$ basic $(H+) < (OH-)$

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

neutrality $(H+ = OH-)$

pH Relationships

It is essential to recognize that pH is not a measurement sensitive to the presence of substances which may contribute to the total acidity or alkalinity of a given sample. Consequently, it must not be confused with the results of total acidity and alkalinity determinations. Samples which possess a neutral pH may possess high acidity and/or alkalinity values. Because natural waters are buffered by the CO_2, HCO_3, CO_3 system to a pH range of 6.5 to 7.5, marked deviations from neutrality are generally the result of industrial or acid mine contamination.

The pH of water samples is usually determined by either colorimetric or electrometric techniques. Colorimetric procedures rely upon chemical substances which undergo color changes with change in pH. There are numerous reagents which demonstrate this phenomenon; however, each is effective as a pH indicator within a limited pH range only. A versatile pH measurement system must contain numerous indicators covering the entire pH spectrum. These indicators are either impregnated on paper strips, used separately in solution form, or combined to create a "universal" or "wide-range" indicator solution.

Electrometric techniques yield the greatest accuracy. They employ meters which, by means of a glass electrode, detect differences in electric potential which occur with differing pH values. Once the meter is properly calibrated, pH readings are read directly from the instrument scale.

Dissolved Oxygen

Dissolved oxygen is an essential substance for the support of most aquatic life. Its concentration in water (normally very low with that in air) varies with fluctuations in such factors as temperature, types and concentrations of dissolved and suspended solids, biotic activity, and agitation of water. Both depressed and elevated (supersaturated) dissolved oxygen levels are encountered in aquatic studies. In view of our understanding of the biological role of DO, deleterious effects of low or non-existent levels of DO are hardly surprising. Harmful effects accompanying DO supersaturation of water supplies have not been so readily anticipated. However, fish have demonstrated low tolerance to DO supersaturation as indicated by an increased incidence of mortality and disease in such waters.

Hardness

Hardness is a water quality parameter which limits the lathering or foaming ability of soaps and increases the tendency of a water sample to produce scale in pipes, heaters and boilers. Hard water is caused by the presence of divalent ions such as Calcium (Ca^{++}) and magnesium (Mg^{++}). Additional ions, e. g., Sr^{++}, Mn^{++}, Fe^{++}, can cause hardness but are present only in limited amounts in most water supplies. If their concentrations are elevated, they should be included in calculations of total hardness. All of these cations enter water sources via industrial wastes, sewage, and contact with soil and rock formations.

Turbidity

Turbidity limits light penetration within a body of water by causing incident light to be scattered or absorbed rather than transmitted appreciable distances through the sample. Turbid water is caused by the presence of suspended organic and inorganic solids derived from erosion, surface drainage systems, and domestic and industrial wastes. It exerts a negative influence on photosynthesis and water temperature by reducing the amount of light reaching subsurface areas and can, by itself, kill fish and other organisms. Increases in turbidity may follow a chain reaction sequence by providing bacteria and other microorganisms contributing to turbidity with an abundant supply of nutrients required for growth and reproduction.

Turbidity is measured by comparing the interference to the passage of incident light in the questioned sample with that in a standard reference. Although the accuracy of photometric

or nephelometric techniques is questionable, such procedures are convenient for approximating turbidity and are used in most commercial kits.

Biochemical Oxygen Demand

BOD values reflect the quantity of molecular oxygen required for the decomposition of organic compounds by aerobic biochemical processes. Consequently, BOD values serve as an index of the pollution strength of wastes by measuring the amount of oxygen which may be removed from water supplies as those waters are being aerobically stabilized.

Bacteriology

There are numerous types of bacteria and most environments are capable of supporting some bacterial life. Certain bacteria, including those used in food processing or those found in the soil, which enable plants to obtain nutrients, are beneficial. Some bacteria, however, cause food to decay and are responsible for various diseases.

Water can contain many types of bacteria in large numbers. Some of these bacteria are harmless to man, but certain types, termed pathogenic, cause diseases such as typhoid fever, dysentary and cholera. The possible danger of disease dictates that water be free of pathogenic bacteria. Because the cultivation of pathogenic forms is difficult and requires trained personnel, a group of more easily cultivated bacteria is used to indicate the possible presence of pathogens. These indicator organisms include total coliform, fecal coliform, and fecal streptococci organisms.

1. Total Coliforms

Total coliforms include a group of rod or stick-shaped organisms characterized by their ability to ferment a specific sugar (lactose) at 35°C within 48 hours. Although coliforms are introduced to water supplies via water runoff from soil, drains, etc., they are considered significant as indicator organisms because of their predominance in the intestinal tracts of warmblooded animals. While not all animal wastes contain pathogens, the excrement of diseased animals and animals serving as carriers of pathogens do present health hazards.

The total coliform density is roughly proportional to the amount of excremental waste present. With exceptions, elevated coliform populations are suggestive of significant contamination by excrement of warm-blooded animals. Several

factors which cause fluctuations in total coliform populations are summarized in the following table.

Factors Influencing Total Coliform Levels

Higher	Lower
1. Sewage intrusion	1. pH changes
2. Nutritive effluents (containing sugar, dairy wastes, etc.)	2. Temperature changes
3. Storm drain overflows	3. Land runoff (prolonged rain)
4. Land runoff (Initial Storms)	4. Toxic Wastes

2. Fecal Coliform

Fecal coliform, a component of the total coliform population, is characterized by its ability to reproduce on a special medium (MFC) at a temperature of 44.5 to 50°C. Because non-fecal coliforms may grow below 44°C, temperature maintenance within the specified tolerance is critical.

Fecal coliforms are gaining notoriety as pollution indicies because of their relatively infrequent occurrence except in association with fecal pollution. Moreover, because survival of the fecal coliform group is shorter in environmental water than for the coliform group as a whole, high fecal coliform levels indicate relatively recent pollution.

When accompanied by fecal streptococci counts, fecal coliform values may aid in the differentiation of animal from human waste (following table). However, caution must be exercised in the interpretation of such data because of technical difficulties in performing precise counts.

Average Individual Density Per Gram of Feces
(Indicator Micro-organisms from Some Animals)

Animal	Fecal Coliform Million	Fecal Streptococci Million	Ratio FC/TS
Man	13.0	3.0	4.4
Duck	33.0	54.0	0.4
Sheep	16.0	38.0	0.4
Chicken	1.3	3.4	0.4
Cow	0.23	1.3	0.2
Turkey	0.29	2.8	0.1
Pig	3.3	84.0	0.04

It is anticipated that national standards for water use will be established according to population densities of fecal coliform as shown in the following table.

Water Quality Criteria With Respect to Fecal Coliform Population

Kind of Water	Recommended Numbers of Fecal Coliforms
1. Water designated for Primary Contact Recreation	1. Should not exceed a mean of 200/100 ml.
2. Water other than for Primary Contact Recreation	2. Should not exceed a mean of 1000/100 ml.
3. General Recreational Surface Water	3. Average not to exceed 2000/100 ml.

Primary Contact Recreational Activities are defined as those activities in which there is a prolonged and intimate contact with the water involving considerable risk of ingesting water quantities sufficient to pose a significant health hazard.

The Food and Drug Administration recommends that the surface waters above shell fish beds shall not have fecal coliform counts above 70/100 ml.

3. Fecal Streptococci

A fecal streptococcus as used in this discussion refers to any streptococcus commonly found in the feces of humans or other warm-blooded animals. Fecal streptococci are spherical organisms which generally occur in pairs or short chains when viewed microscopically. They are capable of reproducing at 45°C and, in some instances, at 10°C on a selective medium containing sodium azide and other inhibitors.

Because fecal streptococci do not occur in pure water or virgin soil, their presence in water supplies indicates the existence of warm-blooded animal pollution. Their validity as an index of pollution is enhanced by their inability to reproduce in water supplies. Moreover, fecal streptococci are resistant to salts. Therefore, this group could have special value for salt water investigation.

Fecal streptococci determinations, when accompanied by fecal coliform studies, serve as a valuable tool in the differentiation of animal from human wastes (see table, page 4). In intestinal wastes of human origin, the ratio of number of fecal coliforms to number of fecal streptococci tends to be greater than four. In comparison, when such

ratios are determined for intestinal wastes from non-human sources, the values tend to be markedly less than 0.7. When interpreting fecal streptococci data, the following three points should be considered:

1. The presence of fecal streptococci in untreated water indicates the presence of fecal pollution by warm-blooded animals.

2. In samples where the source and significance of the coliform group have been questioned, the presence of the streptococcus group should be interpretated as indicating that at least a portion of the coliform group is derived from fecal sources.

3. Because of the uncertainities in die-off rates, the absence of fecal streptococci does not necessarily mean that water is bacteriologically safe.

Incubation

Bacteria need culture media to grow well. The bacteria also need warmth, moisture and darkness to grow rapidly. Therefore, the petri dishes containing the bacteria are placed in an incubator to assure proper conditions.

Procedure:

1. Incubation of total coliforms.

   a. After preparation, invert the petri dishes containing total coliform cultures and place them in a standard incubator for 24 hours at 35± 0.5°C.

      Note: The humidity within the incubator must approach 100%; however, when tightly sealed plastic petri dishes are used, a portion of the broth evaporates, raising the humidity within the dish itself to 100% and adjustment of the humidity outside the dishes is not necessary. If dish covers are loose fitting, the humidity can be maintained by placing a vegetable crisper containing wet towels in the incubator. The dishes are then placed on top of the towels and covered with the crisper's lid.

2. Incubating Fecal Coliform Cultures

   a. After preparation, invert the petri dishes containing fecal coliform cultures and place

them in waterproof plastic bags (3 to 6 dishes per bag).

b. Submerge the bags in waterbath incubator and incubate at 44.5± 0.5°C.

Note: The temperature of the waterbath is critical. Above 45.0°C counts drop rapidly. Below 44.0°C. specificity is lost. Therefore, no more than twenty minutes should elapse between filtration and incubation to prevent non-fecal coliform colonies from developing at lower temperatures. Submergence in waterproof plastic bags reduces the temperature equilibration time considerably.

3. Incubating Fecal Streptococcus Cultures

a. After innoculation, invert the petri dishes containing fecal streptococcus cultures. Place them in a standard incubator for 48 hours at 35± 0.5°C.

Counting Techniques

If all the previous steps were carefully followed, bacterial colonies should now be visible for counting. The results of the count allow us to determine whether the water source is polluted and, if so, how badly.

Procedure:

1. Counting

a. Place the petri dish to be counted under the microscope after removing the lid. Lighting for the counts must be from fluorescent light source as close to directly above the petri dish as possible. The image of the light source is reflected off the colony surfaces into the microscope.

b. Count colonies in an orderly back and forth sweep from top to bottom of the filter using grids as channels. Be sure to avoid mixing any colonies or counting any colonies twice simply because they are in contact with a grid-line. Count all colonies individually. Even if two or more are in contact, almost invariably, they show a fine line of contact. Other individual colonies may have grown to unusual shapes because of particles or fibres

that may have found their way onto the filter membrane. A hand tally is convenient for counting the colonies.

Note: In dishes of total coliform colonies, the coliform colonies demonstrate a greenish metallic luster or "sheen" which may cover the entire surface of the colony or may appear only in the center of the colony. (Any amount of sheen production denotes a coliform colony.) Non-coliform colonies are lighter and do not show this sheen even though they may be shiny. In the fecal coliform dishes, the fecal coliform colonies are blue and all other colonies are cream colored (any amount of blue is positive). Fecal streptococcus colonies have a reddish hue, while other colonies range from cream to clear.

2. Calculations

The count from your membrane must be adjusted for the diluting you did to the sample and the volume filtered. Results should be in coliforms per 100 ml.

Disposal of Cultures

Cultures, whether on filters or in any other medium should be handled with the utmost care, as if they were all potentially dangerous. When you have completed the experiment and observed the results, the cultures should be destroyed or deactivated, and the petri dishes should be resterilized.

POLLUTANT EFFECTS AND TREATMENT REMOVALS

POLLUTANT MATERIAL OR CHARACTERISTIC	EFFECTS ON WATER	PRIMARY REMOVAL	SECONDARY REMOVAL	SECONDARY GAIN ON PRIMARY
Biochemical Oxygen Demand	Creates oxygen demand on the body of water thereby reducing its dissolved oxygen content. When DO falls below a critical level higher aquatic life (fish) dies; with zero DO water becomes septic and odor problem created. Substance comprising BOD may cause foam, discoloration or turbidity.	30%	87%	57%
Coliform Bacteria	An indicator organism which gives a quantitative estimate of the water's bacterial contamination. Indicates when it may be dangerous to eat clams, swim in or drink water.	50%	95%	45%
Undissolved Solids	Inhibit waste reduction by bacteria; create an unaesthetic stream; increase turbidity.	70%	90%	20%
Toxic Substances	At certain levels kill aquatic life; serious sub-lethal effects. Includes pesticides, heavy metals, other poisonous substances.	0%	0%	0%
Oil and Grease	May exert an oxygen demand; coat surface of water and inhibit transfer of oxygen; coat wildlife, river banks, or any other surface with which water body comes in contact.	50%	80%	30%
Detergents	If non-biodegradable may cause foaming; also, may add phosphorus to the water.	0%	20%	20%
Phosphorus	Stimulates the growth of aquatic plants, especially algae; as quantity increases this growth may reach an undesirable level.	10%	30%	20%
Nitrogen	Promotes undesirable aquatic growth.	0%	30%	30%
Color	Aesthetically displeasing.	0%	0%	0%
Lignin	A by-product of pulp manufacturing; creates color problem: gives water a dark brown hue.	0%	0%	0%
Turbidity	Caused by solid and colloidal materials; aesthetically displeasing; may make disinfection more difficult.	30%	90%	60%
Reduced Sulfur Compounds	Leads to creation of odor problems.	0%	0%	0%
Chlorine Residual	May be harmful to aquatic life.	added during treatment		
Acidity/ Alkalinity	Water tends to be corrosive/caustic; destruction of stream life; formation of undesirable chemicals.	0%	0%	0%
Heat	Reduces the capacity of the stream to absorb oxygen; up the use of oxygen by life forms within the water; upsets delicate ecosystems.	60%	90%	30%